METHOD AND APPARATUS FOR FILTERING PRESSURIZED FUEL

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Field of the Invention

The present invention relates to fluid filter assemblies, and more particularly, a diesel fuel or oil filter assembly that operates under high pressure while providing a visual indicator as to the general condition of the filter element.

Background of the Invention

Past fuel filter assembly designs have provided the user with a rough but usable estimate of the condition of the filter element as a function of the height of the fuel level in an upper filter chamber of the fuel filter assembly during operation of the engine. In these designs, fuel moves from a lower chamber of the fuel filter assembly, through a passage, to the upper chamber of the fuel filter assembly. The fuel passes through a cylindrical filter element and out to the engine through an opening at the lower center of the upper chamber. An opaque or transparent cover of the upper filter chamber allows the user to view the fuel level within the upper chamber of the fuel filter assembly so that the user may use the fluid level within the upper chamber as a rough estimate as to the condition of the filter element.

Generally speaking, the fuel level tends to rise in the upper chamber as the filter element becomes more and more clogged from the bottom of the filter element to the top of the filter element. When the fuel level reaches the top of the filter element in normal operation,

this may be taken as the time to consider changing the filter element.

Such fuel filter systems generally run by vacuum, that is, a fuel pump is positioned downstream of the fuel filter assembly, such that the pump is pulling or drawing fuel through the fuel filter assembly. When the fuel pump is placed upstream from the fuel filter assembly, the system is pressurized, and the fuel level within the upper chamber of the fuel filter assembly does not respond in the same manner as the system under vacuum. During low pressure applications, the fuel level may respond in a manner whereby the fuel level can be used to estimate the condition of the filter element. However, under high pressure applications, the fuel level within the upper chamber of the fuel filter assembly rises to the top of the upper chamber immediately, and therefore, does not provide the benefit of having the fuel level provide an estimate as to the condition of the filter element. The inability to run such fuel filter assemblies under high pressure applications reduces the flexibility and applications by which such fuel filter assemblies may be utilized.

It would be desirable to provide a fuel filter assembly that could be used under high pressure applications while still providing the benefits of having the fuel level in the upper chamber of the fuel filter assembly provide an indicator as to the general condition of the filter element.

Brief Description of the Drawings

The description herein makes reference to the accompanying drawings wherein like referenced numerals refer to like parts throughout the several views and wherein:

Fig. 1 is a front view showing the fuel filter assembly of the present invention.

Fig. 2 is a sectional front view of the fuel filter assembly of the present invention.

Fig. 3 is a sectional side view showing the fuel filter assembly of the present invention.

Fig. 4 is an exploded view showing the fuel filter assembly of the present invention.

Fig. 5 is a schematic diagram showing the dimensional relationship between the filter element and the upper chamber of the fuel filter assembly of the present invention.

Fig. 6 is a specification chart showing the dimensional and performance characteristics of the fuel filter assembly of the present invention when used for diesel fuel.

Fig. 7 is a specification chart showing the dimensional and performance characteristics of the fuel filter assembly of the present invention when used with motor oil.

Fig. 8 is a sectional view of the relief valve and thermocouple valve of the fluid filter assembly of the present invention.

Description of the Preferred Embodiment

Referring to the drawings, the present invention will now be described in detail with reference to several illustrative embodiments thereof.

Figs. 1-4 show a fluid filter assembly **10** of the present invention for use in high pressure applications. The fluid filter assembly **10** is ideally suited for filtering and processing diesel fuel and motor oils, but the fluid filter assembly **10** may also be utilized with other fluids, such as gasoline, water, coolant, etc. The fluid filter assembly **10** is mounted vertically upright by two mounting brackets **11**. The fuel filter assembly **10** provides a closed cylindrical housing **12** having a lower fluid storage chamber (not shown) in diesel fuel applications and a base **14** for motor oil applications. An upper filter chamber **16** is threadingly connected to the base **14** or lower storage chamber and is preferably made of a transparent or opaque plastic. A fluid inlet **18** allows fluid to enter the base **14**, and from there, the fluid flows upward to the

upper chamber **16**. A cylindrical filter element **20** is housed within the upper chamber **16** of the housing **12** for filtering the fluid and passing it to a fluid outlet **22**. A relief valve **24** is mounted in the top of the filter element **20** and is designed to open when the pressure level across the filter element **20** reaches a pre-determined level. The relief valve **24** becomes operative only after the filter element **20** becomes substantially clogged, causing the pressure differential across the filter element **20** to rise. The relief valve **24** provides a route for fuel to reach the fluid outlet **22** even though the filter element **20** is clogged. Although not specifically shown, the addition of a secondary filter element may be utilized either upstream or downstream of the relief valve **24**.

To filter contaminates from the fluid, the filter element **20** provides a filter media **21** fabricated from a pleated porous paper material. The filter media **21** encircles a central filter tube **26**, and a fuel impervious plastic cover **28** encircles the outer diameter of the filter media **21**. A plurality of apertures **30** extend through the plastic cover **28** in a lower portion of the filter element **20**. The apertures **30** in the plastic cover **28** allow fuel to pass through the plastic cover **28** to wet the filter media **21**. The ends of the plastic cover **28** and the filter media **21** are contained by top and bottom end caps **32, 34,** respectively. The top and bottom end caps **32, 34** are sealed to the edges of the plastic cover **28** and filter element **20** to preclude any possible leak at the ends of the filter element **20**. A flexible seal **36** is provided on the bottom end cap **34** of the filter element **20** to create a seal between the central filter tube **26** and an inner core **38** of the filter element **20** to assure that unfiltered fluid does not leak into or escape through the fluid outlet **22**. The filter media **21** is preferably pleated or concentrically wound but may also be arranged in any of the ways known to one familiar with filtration construction so as to direct the fluid through the filter element **20**. In addition, the filter element **20** may be

fabricated from a hydrophobic filter material to filter out water from the fluid.

To maintain or relieve the pressure in the upper filter chamber **16** of the housing **12**, the relief valve **24** is mounted in the top end cap **32** of the filter element **20**, as seen in Figs. 1-4 and **8**. The top end cap **32** is fabricated from a thin metallic material having a shape complementary to the top of the filter element **20**. The top end cap **32** has a substantially circular configuration with side walls **40** that extend downward from its periphery to sealingly connect to and cover the top of the filter media **21**. The top end cap **32** also has a centrally located recessed portion **42** which is received by and complementarily engages the inner core **44** of the filter element **20**. A compression spring **46** is seated underneath the bottom end cap **34**. A threaded cap **48** threadingly engages a threaded aperture **50** provided in the upper chamber **16** and forces the filter element **20** against compression spring **46** to maintain the position of the filter element **20**. The threaded cap **48** may also be removed to vent the fluid filter assembly **10** in order to drain the fluid from the fluid filter assembly **10**. The threaded cap **48** may also be removed to prime the fluid filter assembly **10** pouring fluid through the aperture **50** and into the fluid filter assembly **10** prior to threading the cap **48** back into the housing **12**.

In order to have the fluid level in the upper chamber **16** of the fuel filter assembly **10** provide an indication as to the general condition of the filter element **20** under high pressure applications, the spacing between the outer circumference of the fluid impervious cover **28** of the filter element **20** and the inner periphery of the upper chamber **16** becomes critical. The fluid level in the upper chamber **16** of the fluid filter assembly **10** remains an indicator of the general condition of the filter element **20** by having a pocket of trapped air in the upper chamber **16** of the fluid filter assembly **10**. This pocket of trapped air must maintain a certain level of pressure in order to prevent the fluid level from rising when the filter element **20** is not

sufficiently clogged. When the filter element **20** begins to become clogged, the fluid pressure rises thereby compressing the air and increasing the air pressure.

As seen in Fig. 5, the structure of the upper chamber **16** is designed to accommodate this formation of trapped air. The upper chamber **16** is fabricated from a hard, transparent plastic cover **49** having structural ribs **51** to support the cover **49** under high pressure applications. The cover **49** has a larger, inner diameter **52** at a bottom portion of the upper chamber **16** and a smaller, inner diameter **54** at an upper portion of the upper chamber **16**. The spacing between the different diameters **52, 54** of the cover **49** of the upper chamber **16** and the fluid impervious cover **28** of the filter element **20** is critical as this determines the volume of air provided within the upper chamber **16**. The potential volume of air required is determined from the space provided just above the apertures **30** in the plastic cover **28** of the filter element **20**, since air is allowed to pass through the apertures **30** if the fluid extends below the apertures **30** provided in the plastic cover **28** of the filter element **20**.

As seen in Figs. 6-7, the volume of air required in the upper chamber **16** to maintain the effect of the fluid level acting as an indicator to the general condition of the filter element **20** is dependent on the operating pressure of the system. These theories are confirmed by the experimental data shown in Figs. 6-7. In a high pressure system utilizing a conventional diesel fuel as the fluid, as seen in Fig. 6, the system operates at approximately 116 psi when the filter element **20** is clean and at approximately 188 psi when the filter element **20** is ready to be replaced. Through the use of the relationship, $PV = nRT$ (ideal gas law, where P=pressure, V=volume, n=number of molecules, R=gas constant, and T=temperature), and the manufacturing tolerances for the upper chamber **16**, the spacing between the cover **28** of the filter element **20** and the inner diameter of the upper chamber **16** can be determined. Figs. 5-6

show that volume 1 **53**, the large volume, is created by having the cover **28** of the filter element **20** having an outer diameter of substantially 3.82 inches and the inner diameter of the upper chamber **16** having a diameter of substantially 4.82 inches thereby providing a clearance of substantially .5 inches. The height at these diameters is substantially 3.25 inches to provide a volume of substantially 22.05 cubic inches.

Volume 2 **55**, the small vertical volume, is determined by having the outer diameter of the cover **28** of the filter element **20** be substantially 3.82 inches while the inner diameter of the upper chamber **16** is substantially 4.12 inches, thereby creating a clearance of substantially .15 inches. The height of the upper chamber's diameter is substantially 1.5 inches, thereby creating a volume of substantially 2.81 cubic inches.

Volume 3 **57**, the volume above the filter element **20**, has an inner diameter of the upper chamber **16** of substantially 4.12 inches and a height of substantially .2 inches. This provides a volume of substantially 2.67 cubic inches for volume 3 **57**. The total of volumes 1 **53**, 2 **55**, and 3 **57** is substantially 27.75 cubic inches.

When the fuel media **21** is clean, the fuel level rises to the level at which the diameters of the upper chamber **16** change sizes, i.e. up to volume 2 **55**, as the air in volume 3 **57** is compressed into volumes 2 **55** and 1 **53**. This occurs because the volume of air must reach a certain level of pressure to prevent the fluid level from rising to the top of the upper chamber **16**. When the filter element **20** is clean, the system operates at substantially 116 psi while the volume of air is substantially 3.65 cubic inches. As the filter media **21** begins to clog, the fuel level rises and begins to compress the air in volumes 1 **53** and 2 **55**. Since the pressure and volume are determined by PV=nRT, wherein nRT is essentially constant, we know that $P_1V_1=P_2V_2$, wherein P_1V_1 is the pressure and volume when the filter element **20** is clean, and

P_2V_2 is the pressure and volume when the filter element **20** is clogged. When the filter element **20** is clogged, the pressure rises to substantially 188 psi, and the volume is substantially 2.25 cubic inches. When the pressure within volumes 1 and 2 exceeds a predetermined level approximate to that of substantially 188 psi, the relief valve **24** opens, thereby allowing air to escape through the relief valve **24** and allowing the fluid level to rise. The relief valve **24** immediately closes upon the pressure level dropping below the predetermined pressure level.

As previously stated, the volume of air in the upper chamber **16** required to have the fluid level indicate the general condition of the filter element **20** is dependent on the operating pressure of the system. Figs. 5 and 7 show the volume of air required in the upper chamber **16** for an oil filter system which operates at substantially 60 psi when the filter media **21** is clean and operates at substantially 80 psi when the filter element **20** is ready to be replaced. Volume 1 **53**, the large volume, provides a filter element **20** with an outer diameter of substantially 3.82 inches and an inner diameter of the upper chamber **16** having a diameter of substantially 4.57 inches for a clearance of substantially 0.375 inches. The height of the upper chamber **16** at these diameters is substantially 2.75 inches for a volume of substantially 13.59 inches.

Volume 2 **55**, the small vertical volume, provides the filter element **20** with an outer diameter of substantially 3.82 inches and an inner diameter of the upper chamber **16** of substantially 4.02 inches for a clearance of substantially 0.1 inches. The height of the upper chamber **16** at these diameters is substantially 2 inches which provides a volume of substantially 2.46 cubic inches.

Volume 3 **57**, the volume above the filter element **20**, has an inner diameter of the upper chamber **16** of substantially 4.02 inches at a height of substantially 0.2 inches for a volume of substantially 2.54 cubic inches. The total of volumes 1 **53**, 2 **55**, and 3 **57** is

substantially 18.59 cubic inches.

Again, when the filter media **21** is clean, the oil level will start at a level approximating a point at which the inner diameter of the upper chamber **16** changes size thereby forcing the air to compress from volumes 3 **57** to volumes 1 **53** and 2 **55**. Thus, when the filter element **20** is clean, the system pressure is substantially 60 psi, and the volume is substantially 4.06 cubic inches. As the filter element **20** begins to clog, the fluid level will rise, thereby compressing the volume of air in the upper chamber **16**. When the filter element **20** is clogged, the pressure raises to substantially 80 psi, and the volume is reduced to substantially 3.04 cubic inches. When the pressure level within the upper chamber **16** exceeds a predetermined level, such as substantially 80 psi, the relief valve **24** will open, thereby allowing some of the trapped air to escape. The relief valve **24** will immediately close upon the pressure level dropping below the predetermined level.

In extremely cold conditions, the fluid filter assembly **10** may see a rise in the pressure within the upper chamber **16** due to the rise in the viscosity of the fluids. Such a rise in the pressure level may cause the relief valve **24** to open, thereby releasing the air within the upper chamber **16** which is needed to maintain the fuel level at a proper level when the temperature of the fuel filter assembly **10** rises to normal levels. The pressure level will drop as the temperature of the fluid increases with the operation of the vehicle. In order to prevent this unwanted loss of air within the upper chamber **16**, a thermal couple valve **56** is utilized to prevent the relief valve **24** from unnecessarily opening, as seen in Fig. 8. The thermal couple valve **56** provides a thermal sensitive strip of material **57** mounted adjacent the relief valve **34**. A seal **59** mounted at the end of the thermal couple material **57** engages the aperture utilized to allow fluid to pass through the relief valve **34**. In extremely cold weather, the thermal couple

valve **56** remains in the closed position shown in Fig. 8 so as to prevent the relief valve **34** from allowing air to pass through the aperture **61** of the relief valve **34**. When the temperature of the system rises to relatively normal levels, the thermal couple material **57** straightens out and allows the seal **59** on the end of the thermal couple strip **57** to lift off the aperture **61** of the relief valve **24**. Air is then allowed to pass through the aperture **30** when the relief valve **24** opens in response to a predetermined level of pressure.

In operation, the fluid level within the fluid filter assembly **10** rises to a level within the upper chamber **16** where the larger diameter **52** and the smaller diameter **54** of the upper chamber **16** meet. As the fuel level rises to that beginning level, the air within the upper chamber **16** is compressed into volumes 2 **55** and 3 **57** . As the filter media **21** clogs, the level of fluid in the upper chamber **16** rises thereby compressing the air further. When the pressure reaches a predetermined level, the relief valve **24** opens thereby allowing air to escape from the upper chamber **16** until the pressure within the upper chamber **16** drops below the predetermined pressure level. When the fluid rises to the top of the upper chamber **16**, the filter element **20** may be replaced.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims, which scope is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures as is permitted under the law.